JP-8 REFORMATION FOR FUEL CELL APPLICATIONS

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ABSTRACT

Military jet fuel (JP-8) has been successfully reformed to produce synthesis gas (hydrogen and carbon monoxide) selectively with a rhodium-based catalyst. Time-on-stream experiment indicates that the catalysts remains stable and active for at least 4 hours using a jet fuel (310ppm sulfur) straight from the pump without pre-reforming sulfur removal. The dry gas composition of the product (reformate) includes about 15 % hydrogen, 20% CO, 1% methane, 58% nitrogen and others. This JP-8 reformer can potentially be integrated with a reformate sulfur sorption bed and a solid oxide fuel cell for tactical power applications.

1. INTRODUCTION

A source of hydrogen has been the major technical barrier to utilize fuel cells as power sources in the Future Combat Systems. Reformers generate hydrogen by breaking down hydrocarbons through catalytic processes. An integrated system of a fuel reformer and a fuel cell can provide portable and mobile power for battery chargers and scout vehicle silent watch. In the past few years Schmidt and others have demonstrated the feasibility of reforming heavy hydrocarbons (e.g. octane, decane, and hexadecane) in a short contact time reactor (Krummenacher et al.). JP-8 is a complex mixture of heavy hydrocarbons with organosulfur impurities, and we need to study the capability of this reforming technology to convert JP-8 directly for fuel cell applications.

The objective of the present study is to develop advanced catalytic reforming materials and processes to utilize military JP-8 for solid oxide fuel cell (SOFC) applications. The catalytic partial oxidation converts the fuels in the presence of oxygen (from the air) to a mixture of carbon monoxide and hydrogen.

$$C_{10}H_{22} + 5\ O_2 \rightarrow 11\ H_2 + 10\ CO,\ \Delta H = -192\text{kcal/mol} \quad (1)$$

Since both carbon monoxide and hydrogen are the fuels for SOFC, a carbon monoxide removal step is not necessary. In addition to syngas (CO and H_2) production, the reformer also converts over one hundred organosulfur impurities into a few inorganic sulfur compounds (mainly H_2S). Pre-reforming and post-reforming sulfur traps are usually required to remove organosulfur and inorganic sulfur compounds, respectively.

2. EXPERIMENTAL

The jet fuel sample was a military JP-8 from Fort Belvoir. The fuel was collected at a fueling pump without any sulfur removal procedures before our reforming experiments. The fuel was analyzed independently with the Antek total sulfur analyzer and the Sievers sulfur chemiluminescence detector coupled with gas chromatography. Both analyses indicated that the fuel sample contains about 310 ppm sulfur.

The reforming experiments of the JP-8 were performed in a short contact time reactors similar to previous reports, but we built the reactor with a second fuel injector for water injection. We fed the fuel and the water into the quartz reactor through a preheat/mixing region. The catalyst was a rhodium-based catalyst supported on monolithic foam. We analyzed the reformate composition with gas chromatography. Since JP-8 was a complex hydrocarbon mixture, the conversion of JP-8 was estimated by assuming that all molecules bigger than C8 are reactants. This estimation gave a lower bound to the fuel conversion, and the actual conversion was higher than the value reported here.

The time-on-stream experiments were performed in the same reactor system. Every 3 minutes the reformate

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **00 DEC 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Jp-8 Reformation For Fuel Cell Applications**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **AMSRD-ARL-SE-DC US Army Research Laboratory 2800 Powder Mill Road Adelphi, MD 20783; Department of Chemical Engineering and Materials Science University of Minnesota 412 Washington Ave SE Minneapolis, MN 55455**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM001736, Proceedings for the Army Science Conference (24th) Held on 29 November - 2 December 2005 in Orlando, Florida. , The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

was automatically sampled for gas analysis with an Agilent multi-channel micro gas chramotagraphy.

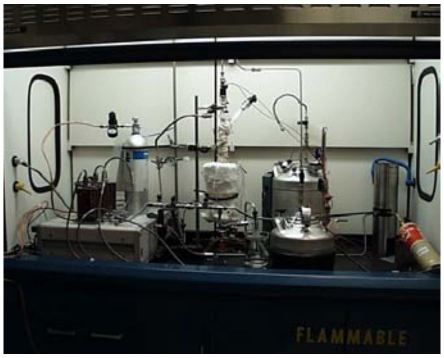

Fig. 1 JP-8 reformer at Army Research Laboratory

3. RESULTS AND DISCUSSION

We have evaluated our reforming technology with a military JP-8 fuel from Fort Belvoir. This JP-8 contained about 300 ppmw sulfur. We built a dual-injector reactor to investigate the heavy hydrocarbon reformation under dry conditions or with steam addition. In steam addition experiments, we used steam-to-carbon ratio of 1 (H_2O/C =1). These steam addition experiments simulate recycling steam from SOFC. When the reformer is integrated with a SOFC, the H_2O/C ratio of 1 is the maximum H_2O/C ratio without addition of external water. Under dry conditions, the JP-8 conversion remained above 80% with a C/O ratio from 0.7 to 2.0. At low C/O ratio the main products were hydrogen and carbon monoxide, while at high C/O ratio the main products were olefins. Since the preferred fuels for solid oxide fuel cells are H_2 and CO, one would like to run a C/O ratio of 0.7 or 0.8 for fuel cell applications. With steam addition (H_2O/C =1), the JP-8 conversion remained high for C/O <1.3. The catalytic temperatures with steam addition were typically lower that the catalytic temperatures under dry conditions by 100-150^oC. Catalyst temperatures of 750^oC were too low to sustain 80% fuel conversion. Steam addition also reduced the undesired carbon deposition.

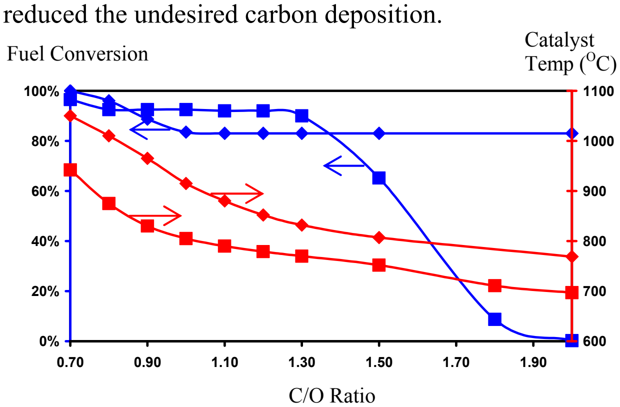

Fig. 2 JP-8 reformation with H2O/C =0 [♦] or =1 [■]

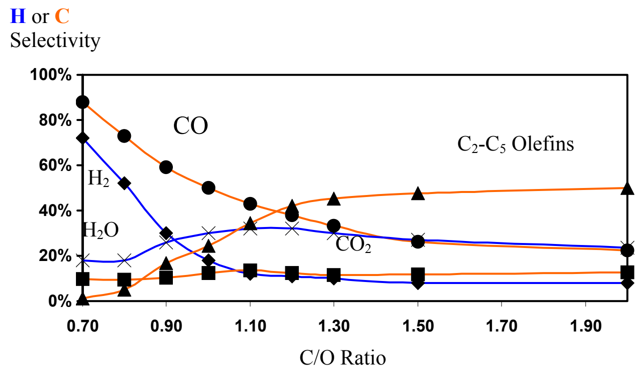

Fig. 3 Low C/O ratio favors hydrogen generation for SOFC

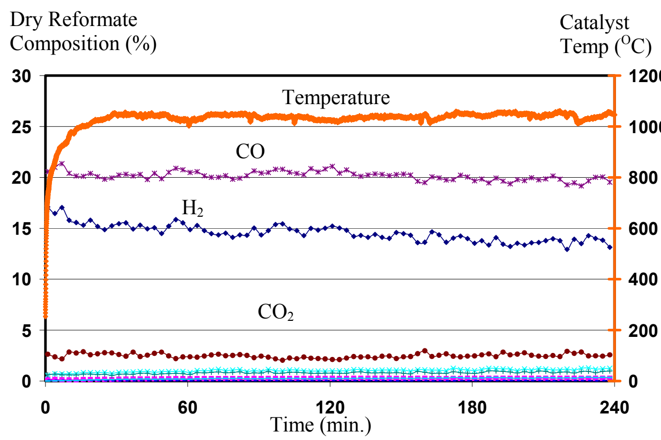

Fig. 4 Time-on-stream experiment for JP-8 reforation under dry conditions.

ACKNOWLEDGEMENTS

This work is sponsored by the Army Research Laboratory Power & Energy Collaborative Technology Alliance (P&E CTA), DAAD19-01-2-0010.

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CONCLUSIONS

We have demonstrated the feasibility of reforming a military JP-8 directly without pre-reforming sulfur removal. We can tune the JP-8 reformer to produce hydrogen selectively. Our reforming technology gives high yields of CO and H_2 for solid oxide fuel cell APU applications. Reformation studies of long term durability and sulfur tolerance limits are in progress.